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UTILITY  
PATENT APPLICATION  
TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No. 102047-0003

First Inventor or Application Identifier Orville J. Birkestrand

Title MODULAR MOTORIZED ELECTRIC WHEEL HUB ASSEMBLY FOR  
BICYCLES AND THE LIKE

Express Mail Label No. EL024419110US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility application contents

ADDRESS TO:

Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1. ☒ \*Fee Transmittal Form (e.g., PTO/SB/17)

(Submit an original and a duplicate for fee processing)

2. ☒ Specification [Total Pages 23 ]  
(preferred arrangement set forth below)

- Descriptive title of the invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the invention
- Brief Summary of the invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. ☒ Drawing(s) [Total Sheets 7 ]

4. Oath or Declaration [Total Pages ]

- a ☒ Newly executed (original copy)
- b ☐ Copy from a prior application (37 C.F.R. § 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 5 below]

DELETION OF INVENTOR(S)

- i ☐ Signed statement attached deleting  
inventor(s) named in the prior application,  
see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b)

5 ☐ Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a  
copy of the oath or declaration is supplied under Box 4b, is  
considered to be part of the disclosure of the  
accompanying application and is hereby incorporated by  
reference therein

6. ☐ Microfiche Computer Program (Appendix)

7. Nucleotide and/or Amino Acid Sequence Sequence  
Submission

((if applicable, all necessary))

- a. ☐ Computer Readable Copy
- b. ☐ Paper Copy (Identical to computer copy)
- c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8 ☐ Assignment Papers (cover sheet & document(s))

9. ☐ 37 C.F.R. §3.73(b)  
☐ Statement (when there is ☒ Power of Attorney  
an assignee)

10 ☐ English Translation Document (if applicable)

11 ☐ Information Disclosure  
Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)

\*Small Entity  
14. ☒ Statement(s) ☐ Statement filed in prior application,  
((PTO/SB/09-12) Status still proper and desired

15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)

16 ☐ Other

NOTE FOR ITEMS 1 & 14: IN ORDER TO BE ENTITLED TO  
PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS  
REQUIRED (37 C.F.R. §1.27). EXCEPT IF ONE FILED IN A  
PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information below and in a preliminary amendment:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No. /

Prior application Information: Examiner

Group/Art Unit:

18. CORRESPONDENCE ADDRESS

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Date

May 11, 1998

# FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1.

These are the fees effective October 1, 1997.

Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12.

See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT (\$ ) 582

## Complete If Known

|                      |                        |
|----------------------|------------------------|
| Application Number   | Not Yet Assigned       |
| Filing Date          | May 11, 1998           |
| First Named Inventor | Orville J. Birkestrand |
| Examiner Name        | Not Yet Assigned       |
| Group / Art Unit     | Not Yet Assigned       |
| Attorney Docket No.  | 102047-0003            |

### METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number   
 Deposit Account Name

- ☒ Charge Any Additional Fee Required Under 37 C.F.R. §§1 16 and 1 17 ☐ Charge the Issue Fee Set in 37 C.F.R. §§1 18 at the Mailing of the Notice of Allowance

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### FEE CALCULATION

#### 1. BASIC FILING FEE

| Large Entity<br>Fee Code | Small Entity<br>Fee Code | Fee (\$) | Fee (\$) | Fee Description        | Fee Paid |
|--------------------------|--------------------------|----------|----------|------------------------|----------|
| 101                      | 790                      | 201      | 395      | Utility filing fee     | 395      |
| 106                      | 330                      | 206      | 165      | Design filing fee      |          |
| 107                      | 540                      | 207      | 270      | Plant filing fee       |          |
| 108                      | 790                      | 208      | 395      | Reissue filing fee     |          |
| 114                      | 150                      | 214      | 75       | Provisional filing fee |          |
| SUBTOTAL (1) (\$ )       |                          |          |          |                        | 395      |

#### 2. EXTRA CLAIM FEES

| Total Claims | Independent Claims | Multiple Dependent | Extra Claims | Fee from below | Fee Paid |
|--------------|--------------------|--------------------|--------------|----------------|----------|
| 37           | 2                  |                    | 20**         | 17             | 187      |
|              |                    |                    | 3**          | 0              | 0        |
|              |                    |                    |              |                | 0        |

\*\*For number previously paid, if greater, For Reissues, see below

#### Large Entity Small Entity

| Fee Code | Fee (\$) | Fee Code | Fee (\$) | Fee Description   |
|----------|----------|----------|----------|---|
| 103      | 22       | 203      | 11       | Claims in excess of 20                                    |
| 102      | 82       | 202      | 41       | Independent claims in excess of 3                         |
| 104      | 270      | 204      | 135      | Multiple dependent claim, if not paid                     |
| 109      | 82       | 209      | 41       | **Reissue independent claims over original patent         |
| 110      | 22       | 210      | 11       | **Reissue claims in excess of 20 and over original patent |

SUBTOTAL (2) (\$ ) 187

### FEE CALCULATION (continued)

#### 3. ADDITIONAL FEES

| Large Entity<br>Fee Code               | Small Entity<br>Fee Code | Fee (\$) | Fee (\$) | Fee Description  | Fee Paid |
|--|--------------------------|----------|----------|--|----------|
| 105                                    | 130                      | 205      | 65       | Fee Surcharge - late filing fee or oath                                    |          |
| 127                                    | 50                       | 227      | 25       | Surcharge - late provisional filing fee or cover sheet                     |          |
| 139                                    | 130                      | 139      | 130      | Non-English Specification  |          |
| 147                                    | 2,520                    | 147      | 2,520    | For filing a request for reexamination                                     |          |
| 112                                    | 920                      | 112      | 920*     | Requesting publication of SIR prior to Examiner action                     |          |
| 113                                    | 1,840                    | 113      | 1,840*   | Requesting publication of SIR after Examiner action                        |          |
| 115                                    | 110                      | 215      | 55       | Extension for reply within first month                                     |          |
| 116                                    | 400                      | 216      | 200      | Extension for reply within second month                                    |          |
| 117                                    | 950                      | 217      | 475      | Extension for reply within third month                                     |          |
| 118                                    | 1,510                    | 218      | 755      | Extension for reply within fourth month                                    |          |
| 128                                    | 2,060                    | 128      | 1,030    | Extension for reply within fifth month                                     |          |
| 119                                    | 310                      | 219      | 155      | Notice of Appeal   |          |
| 120                                    | 310                      | 220      | 155      | Filing a brief in support of an appeal                                     |          |
| 121                                    | 270                      | 221      | 135      | Request for oral hearing   |          |
| 138                                    | 1,510                    | 138      | 1,510    | Petition to institute a public use proceeding                              |          |
| 140                                    | 110                      | 240      | 55       | Petition to revive - unavoidable   |          |
| 141                                    | 1,320                    | 241      | 660      | Petition to revive - unintentional   |          |
| 142                                    | 1,320                    | 242      | 660      | Utility Issue fee (or reissue)   |          |
| 143                                    | 450                      | 243      | 225      | Design Issue fee   |          |
| 144                                    | 670                      | 244      | 335      | Plant Issue fee  |          |
| 122                                    | 130                      | 122      | 130      | Petitions to the Commissioner  |          |
| 123                                    | 50                       | 123      | 50       | Petitions related to provisional applications                              |          |
| 126                                    | 240                      | 126      | 240      | Submission of Information Disclosure Stmt                                  |          |
| 581                                    | 40                       | 581      | 40       | Recording each patent assignment per property (times number of properties) |          |
| 146                                    | 790                      | 246      | 395      | Filing a submission after final rejection (37 CFR 1.129(a))                |          |
| 149                                    | 790                      | 249      | 395      | For each additional invention to be examined (37 CFR 1 129(b))             |          |
| Other (specify)<br>Other fee (specify) |                          |          |          |  |          |
| SUBTOTAL (3) (\$ )                     |                          |          |          |  | 0        |

\*Reduced by Basic Filing Fee Paid

### SUBMITTED BY

Typed or Printed Name John F. McKenna

Signature

Date

May 11, 1998

### Complete (if applicable)

Reg. Number 20,912

Deposit Account User ID

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

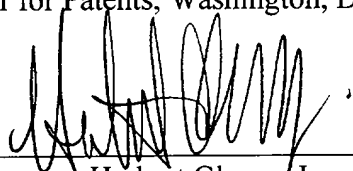
In Re The Application of: )  
Orville J. Birkestrand )  
Serial No.: Not Yet Assigned ) Examiner: Not Yet Assigned  
Filed: May 11, 1998 ) Art Unit: Not Yet Assigned  
For: MODULAR MOTORIZED ELEC- )  
TRIC WHEEL HUB ASSEMBLY )  
FOR BICYCLES AND THE LIKE )

Cesari and McKenna, LLP  
30 Rowes Wharf  
Boston, MA 02110  
May 11, 1998

**CERTIFICATE OF EXPRESS MAILING**

“Express Mail” Mailing-Label Number: EL024419110US

I hereby certify that the following United States Patent Application, Informal Drawings (7 sheets), Declaration and Power of Attorney for Patent Application, Small Entity Declaration, Utility Patent Application Transmittal, Fee Transmittal and check in the amount of \$582.00 are being deposited with the United States Postal Service “Express Mail Post Office to Addressee” service pursuant to 37 C.F.R. §1.10 in an envelope addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231, on May 11, 1998.

  
Herbert Glover, Jr.

**UNITED STATES PATENT APPLICATION**

*of*

**Orville J. Birkestrand**

*for a*

**MODULAR MOTORIZED ELECTRIC WHEEL HUB ASSEMBLY FOR  
BICYCLES AND THE LIKE**

This invention relates to a modular motorized wheel hub for bicycles, scooters, golf carts and other on and off road vehicles. It relates more particularly to a compact electric modular motor/wheel hub assembly which develops sufficient torque to power a variety of vehicles.

5

### BACKGROUND OF THE INVENTION

There are numerous vehicles in use today which have battery-powered electric motors to drive the wheels of the vehicle. These include bicycles, adult tricycles, wheel chairs, motor scooters, golf carts, all terrain vehicles, etc. In many such vehicles, the motor is mounted to the vehicle frame with the motor output being coupled to the wheels by way of a chain drive, gear train or the like.

There also exist in the prior art various bicycles which have an electric motor connected directly to a wheel hub and arranged to rotate that hub. In some cases, the motor is mounted outside the wheel hub and takes up considerable space; see e.g., Patent 5,622,187. These are not modular assemblies. In other instances, the motor takes the place of the usual wheel hub and rotates the rim of wheel; see, e.g., Patents 5,271,527; 5,272,938; 5,341,892 and 5,581,136. Such motors are also relatively large, occupying a large percentage of the area within the associated wheel rim.

There do exist a few examples of bicycle-type vehicles whose motor is located entirely within the hub of the wheel; see e.g., Patents 572,036; 2,514,460 and 3,921,741. As to these, in some cases the hub assembly is overly wide so that it cannot be mounted to the fork of a conventional bicycle frame. In other cases, the assembly is composed of a multiplicity of separate parts which are difficult to make and do not assemble as one unit. However, the most serious disadvantage of prior motorized hub assemblies of this general type is that they tend to overheat when used for a prolonged period as the bicycle's or other vehicle's sole source of power. In other words, while those prior assemblies may operate satisfactorily as a power assist device, when used alone to drive the vehicle, they either consume too much power and drain the associated battery after only a relatively short time or they do not develop sufficient torque to enable the vehicle to travel at a sufficient speed particularly on upgrades.

## SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved modular motorized wheel hub assembly for bicycles and other vehicles.

Another object of the invention is to provide a modular motorized hub assembly of this type which is comparable in length and diameter to a conventional non-motorized wheel hub.

A further object of the invention is to provide such a modular assembly which is composed of a minimum number of separate parts which can be assembled as one unit without requiring any special tools or other equipment.

Another object of the invention is to provide a modular motorized hub assembly  
5 which provides a high torque output in a compact package and allows use of a high speed motor to minimize the package size and weight.

A further object of the invention is to provide a motorized wheel hub assembly which does not become overheated in use.

A further object of the invention is to provide a modular motorized wheel hub as-  
10 sembly which has an extremely wide band efficiencies over a wide range of speeds.

Another object of the invention is to provide such an assembly which can also function as a motor generator to recharge the assembly's DC power source and provide a controllable electric vehicle brake.

A further object of this invention is to provide a controllable electric hub assem-  
15 bly of this type having an absolute minimum number of electrical conductors that have to be brought to outside connectors to allow all of them to pass through a small central shaft of the assembly.

Other objects will, in part, be obvious and will, in part, appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the following detailed description, and the scope of the invention will be indicated in the claims.

In general, my assembly comprises modular DC electric motor incorporated into a  
5 wheel hub having stationary collinear shafts projecting from opposite ends of the hub.  
The motor stator is mounted inside a stationary stator case or shell inside the hub which  
case is connected to one of the shafts. Planet gears comprising a gear reducer are rotata-  
bly mounted to the case which gears mesh with a ring gear formed on the inside wall of  
the hub. These planet gears are rotated by a small diameter sun gear or pinion which ro-  
10 tates with a motor rotor positioned within the stator. Electrical connections to the stator  
are made through one of the shafts by which power may be provided to the stator causing  
the rotor to rotate. The rotor turns the pinion which then rotates the planet gears causing  
the hub to rotate relative to the shafts which are fixed in use.

A sprocket with a one-way clutch may be incorporated into the hub assembly so  
15 that if the motor rotates the hub faster then the sprocket is rotated (as on a power-assisted  
bicycle), the sprocket will free wheel. In addition, if the associated wheel is braked or  
raised from the ground and rotated manually, the motor can function as a generator to re-  
charge the batteries that power the motor.

The hub is sealed from the atmosphere and internal lubrication channels are pro-  
20 vided for circulating a fluid which transfers heat from the motor in the stator case and the



gear reducer to the hub where it is conducted to the outside thereby allowing the motor to operate with a high torque output for a prolonged period without overheating.

The motor is basically a high performance, variable speed, brushless, sensorless, internally cooled, three-phase, computer balanced motor/generator with extremely wide  
5 band efficiencies approaching 95% with 90% efficiency down to and below 20% maximum speed. This high performance motor is married to an unusually small very efficient planetary gear reducer resulting in an unusually compact motorized hub assembly for a vehicle.

As will be seen later, the modular assembly is composed of a minimum number of  
10 parts which are relatively easy to make and to put together as one unit. Therefore, the assembly should be economical to make in quantity.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

For a fuller understanding of the nature and objects of the invention, reference  
15 should be made to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a bicycle incorporating motorized hub assemblies according to the invention in the front and rear wheels of the bike;

FIG. 2 is a longitudinal sectional view of the hub assembly in the front wheel of  
20 the FIG. 1 bike;

FIG. 3 is an exploded elevational view showing the components of the gear reducer in the FIG. 2 assembly in greater detail;

FIG. 4 is a plan view taken along line 4-4 of FIG. 3;

FIG. 5 is a plan view taken along line 5-5 of FIG. 3;

5        FIG. 6 is a fragmentary sectional view of another motorized hub assembly embodiment that drives the rear wheel of the FIG. 1 bicycle;

FIG. 7 is a view similar to FIG. 2 of still another motorized hub assembly embodiment incorporating the invention;

FIG. 8 is a fragmentary sectional view showing an automobile wheel having a hub  
10    assembly incorporating the invention;

FIG. 9 is a sectional view similar to FIG. 7 of still another hub assembly embodiment, and

FIG. 9A is a fragmentary sectional view on a larger scale illustrating the FIG. 9 assembly with a two-stage gear reducer.

15        **DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT**

Refer now to FIG. 1 which shows a bicycle which includes a more or less standard frame 10 with upper and lower reach bars 12 and 14, a head post 16 mounted to the forward ends of the reach bars, a front fork 18 rotatably mounted to head post 16, the front fork being rotated by handle bars 22. A front wheel 24 is rotatably mounted between the tines of the front fork 18, the wheel including a rim 24a connected by radial  
20

spokes 24**b** to a motorized hub assembly 26 incorporating the invention and mounted to the lower end of the front fork 18.

The upper and lower reach bars 12 and 14 extend back to a seat post 28, with the lower end of the seat post and the lower reach bar joining at a sprocket tube 32 which ro-  
5 tatably supports a pedal sprocket 34. Extending rearwardly from the sprocket tube is a rear fork 36 which, along with a bifurcated rear brace 38 rotatably supports a rear wheel 42. Wheel 42 includes a rim 42**a**, and radial spokes 42**b** which extend to a hub assembly 44 according to the invention and mounted to the rear end of rear fork 36. In the bicycle depicted in FIG. 1, the hub assembly 44 includes a rear sprocket 46 which is connected  
10 by a chain 48 to pedal sprocket 34.

A battery pack/control unit 52 is supported on a rack 53 extending rearwardly from seat post 28 over the rear wheel 42 which rack is braced by a pair of struts 53**a** ex-  
tending down to the rear axle of the bike. Unit 52 is connected by 3-wire cords 53 one each to hub assemblies 26 and/or 44 and one to a combination electronic throttle regen-  
15 erative brake control 54 incorporated into handlebars 22. When actuated, control 54 causes control unit 52 to operate hub assembly 44 in a regenerative braking mode so that the forward motion of the bike may be slowed or stopped. A conventional hand operated caliper brake (not shown) may be associated with the front wheel rim 24**a**.

Thus, the bicycle in FIG. 1 can be powered by the rider pedaling on crank 34  
20 and/or by the motorized front wheel hub assembly 26 and/or by the motorized rear wheel

hub assembly 44. Also, of course, either the front hub assembly 26 or the rear hub assembly 44 may be replaced by a conventional front or rear wheel hub.

Refer now to FIG. 2 which shows the front wheel hub assembly 26 in greater detail. That assembly comprises modular brushless, sensorless, 8-pole DC electric motor shown generally at 62 which drives a single stage planetary gear reducer indicated generally at 64 so as to rotate an outer hub 66 relative to a pair of collinear stub shafts 68 and 72 which, in use, are fixed to the lower end of the bicycle's front fork 18 (FIG. 1). Hub 66 is connected by spokes 24b to the wheel rim 24a so that when the motor 62 is energized by the battery pack/control unit 52 (FIG. 1), the rotator rotates the wheel 24.

Motor 62 comprises a cup-like stator case 74 having a cylindrical side wall 74a and a generally discoid end wall 74b. The shaft 68 extends out axially from the center of end wall 74b. The stator case 74 contains a lamination stack 76 and a toroidal 3-wire, 3-phase WYE-connected winding 78. The three winding wires 78a, 78b and 78c are brought out of case 74 through a passage 82 in the case end wall 74b and shaft 68, those wires extending to a 3-pole connector 84 incorporated into the outer end of shaft 68. To facilitate conducting the wires out of the case, the shaft 68 may be formed as a tube as shown and filled with a plug 86 of an epoxy material. Alternatively, the shaft 68 may be a separate piece from the case 74 press fit to the case end wall 74b from the inside thereof. In that event, integral tabs on the shaft may engage slots in the end wall of the stator case 74 to rotatably fix the shaft to the case. This construction allows the wires

78a-78c from winding 78 to be threaded through shaft 68 before the shaft and winding are seated in the stator case 74. This somewhat simplifies the threading of those wires.

Also positioned in the stator case 74 at the axis of winding 78 is a cup-like rotor 88 having a cylindrical side wall 88a and an end wall 88b which faces the open end of the stator case 74. A tubular shaft 92 projects axially from the center of end wall 88b to a location just beyond the open end of shell 74. The rotor has eight generally rectangular, longitudinally extending, alternately north and south pole permanent magnets 89 spaced around its circumference.

Still referring to FIG. 2, in order to rotatably mount rotor 88 at the axis of the hub assembly 26, the shaft 68 is provided with an inner end extension 68a which projects into case 74. That extension is stepped in order to seat the inner race of a circular bearing 94, the outer race of which is received in a counterbore 96 present at the open end segment of the rotor side wall 88a. Preferably, a spring washer 98 is present between bearing 94 and its seat in shaft extension 68a to provide compliance and to preload the bearing to minimize noise when the assembly is in operation.

The rotor end wall 88b and tubular shaft 92 projecting therefrom have an axial passage 102 which is tapered for reasons that will become apparent. Also, the radially outer wall of shaft 92 is stepped in order to provide a seat for the inner race of a circular bearing 104.

As best seen in FIGS. 2 to 4, the open end of the stator case 74 is closed by an annular end cap 106 to form a motor housing. The end cap includes a circular flange or side

5 wall 106a which is exteriorally threaded to mate with similar threads 108 inscribed in the stator case side wall 74a at the open end of the case. Preferably, an O-ring 109 is placed between those two elements to provide compliance and a fluid-tight seal there. The threads are glued at final assembly so that the structure can transmit torque in both direc-  
5 tions without unscrewing.

The end cap 106 is also provided with a radially inner circular flange or collar 110 which forms a seat for the outer race of bearing 104 so that when the end cap is tightened onto the stator case 74, the opposite ends of the rotor are rotatably supported by their re-  
10 spective bearings 94 and 104 for rotation about the common axis of the shafts 68 and 72 which constitutes the rotary axis of the hub assembly 26 as a whole. Also, when cap 106 is tightened onto case 74, the cap side wall or flange 106a compresses the lamination  
stack 76 of the motor thereby taking up any dimensional tolerances between the lamina-  
tion stack length and the various machined parts of the motor and minimizing any eddy  
current losses in the motor. Thus the stator case 74 and cap 106 fully enclose the internal  
15 elements of motor 62, i.e., they form a sealed stator case that protects those elements from the environment outside the motor. In this connection, we should mention that the bearing 104 which is seated in end cap 110 is a sealed bearing so that fluids from the  
outside cannot pass through that bearing into case 74.

Still referring to FIGS. 2 to 4, end cap 106 also carries components of the gear re-  
20 ducer 64. More particularly, a plurality of posts 112 project from the outer face of cap 106. In the illustrated assembly, there are four such posts 112 arranged in a circle. Two

of these posts, i.e., the upper and lower ones, function as axles for a pair of annular planet gears 114 which are rotatably mounted to those axles by way of circular bearings 116. Preferably, the posts and the inner walls of the gears are stepped to provide seats for the bearings with the outer races of the bearings being retained on their respective gears by  
5 snap rings 118 (FIG. 2).

The planet gears 114 mesh with a small diameter sun gear or pinion 122 projecting axially from the rotor shaft 92 between those gears. The sun gear includes a shaft extension 122a which is dimensioned and tapered so as to wedge very tightly into the tapered passage 102 in rotor shaft 92 so that the sun gear and rotor turn in unison.

10 The posts 112 extend out somewhat beyond the bearings 116 which support the planet gears 114. This allows the bearings, and therefore the gears, to be captured by a rigid retaining disk 124 mounted coaxially to the inner end of the assembly's shaft 72. More particularly, the inner face of disk 124 is formed with a circular array of four receptacles or sleeves 126 which are dimensioned and arranged to receive the projecting ends  
15 of posts 112, with the ends of the upper and lower sleeves bearing against the inner races of the bearings 116. Thus, the planet gears 114 are secured to the stator case end cap 106 but can be rotated about their axes by the sun gear 122 which is spaced slightly from disk 124 as shown in FIG. 2 so that there is minimal frictional contact between the sun gear and the disk.

Preferably, the disk 124 is releasably secured to end cap 106 by threaded fasteners 125 which extend through holes 127 in disk 124 and are turned down into threaded passages 129 in posts 112.

Referring to FIG. 2, the assembly's hub 66 is a cup-like member which is arranged to receive and surround motor 62 and the planet gears 114 of the gear reducer 64. Hub 66 includes a cylindrical side wall 66a and an annular end wall 66b which may be slightly dished as shown in FIG. 2. The end wall 66b has a central opening 128 which provides clearance for shaft 72. Opening 128 is counterbored to provide a seat for the outer race of a self lubricating and sealed shaft bearing 132 which allows hub 66 to rotate freely relative to that shaft. Preferably, a dished washer 134 is present between bearing 132 and end wall 66b to provide compliance, allowing the assembly to be more accommodating to slight dimensional variations of parts and to preload the bearing to minimize noise and vibration.

The final component of gear reducer 64, namely a ring gear 136, is formed on the inside surface of hub side wall 66a opposite planet gears 114. As shown in FIG. 2, the planet gears 114 extend out somewhat beyond the side wall of motor 62 so as to mesh with the teeth of the ring gear 136.

The motor 62 and the components of the gear reducer 64 are assembled to hub 66 by sliding them, shaft 72 first, into the open end of the hub until disk 124 seats against bearing 132. They are retained within the hub by an annular end cover 138. The end cover has a central passage 142 which provides clearance for the assembly's shaft 68,



there being a circular, self-lubricating and sealed shaft bearing 144 provided between the shaft and the wall of passage 142 so that the end cover 138 is free to rotate along with hub 66 relative to shaft 68. The periphery of the end cover 138 is threaded so that the end cover can be screwed into the open end of hub 66. For that, the inner wall of the hub side wall 66a has internal threads 146 which mate with the threads on the end cover. When the end cover is screwed tightly to the hub, all of the components of the assembly are held together in the proper coaxial relationship. Preferably, an O-ring 148 is present between the end cover and the hub to provide a fluid tight seal at that location and the threads are glued to prevent unscrewing in operation.

It will be apparent from the foregoing that when my assembly is in use, shafts 68 and 72 which are mounted to the bicycle frame 10 (FIG. 1) are stationary as is stator case 74, end cap 106 and retaining disk 124 which are all secured together. Therefore, when the stator winding 78 of motor 62 is energized, rotor 88 and sun gear 122 connected thereto rotate at a speed which may be varied from 0 to 4000 RPM or higher. The sun gear, in turn, rotates the planet gears 114 of gear reducer 64 which, in turn, cause hub 66 carrying ring gear 136 to rotate. In a typical assembly, the sun gear 122 may have 6 teeth and each planet gear 114 may have 30 teeth while the ring gear 136 may have 66 teeth. This gives the single stage gear reducer 64 a gear reduction ratio of 11:1.

It is important to note at this point that my hub assembly does not have a through shaft. In other words, the sun gear or pinion 122 which is connected to motor rotor 88 is completely separate from both shafts 68 and 72. Therefore, it is subjected to no bending

forces. This means that the sun gear or pinion 122 on the bike models can be very small, e.g., 0.50 in. in diameter. This, in turn, allows the use of large diameter planet gears so that the single stage gear reducer 64 can provide a large gear reduction, e.g., 11:1, in a small package. This efficient compact larger gear reduction, for a given output speed and torque, allows a higher RPM motor, which, in turn, allows the motor and entire hub to be made much smaller for a given power rating.

It is also a feature of the invention that the assembly's motor 62 has a stationary stator which is located very close to the side wall 66a of the rotary hub 66, being separated by a narrow, e.g., 0.15 in., annular gap 152. This means that there is efficient transfer of heat generated in the winding 78 to the hub side wall 66a which heat is then dissipated to the outside. To accelerate this process, the hub side wall 66a may be provided with a series of circumferential cooling fins 66a to increase the exterior surface area of the side wall.

Cooling of the modular assembly may be optimized by circulating a cooling agent or lubricant within the assembly. More particularly in the FIG. 2 assembly, the shaft 72 is provided with an axial passage 154 and an oil or grease fitting 156 at the outer end of the shaft which allows a lubricant such as oil O to be introduced into the assembly so that the oil fills hub 66 up to the level of an internally threaded oil level passage 158 present in the hub end wall 66b. When the oil O reaches the desired level, the passage 158 may be closed by a threaded plug 162.

When the assembly is stationary, the oil O collects at the bottom of the assembly at a level below that of the self-lubricating and sealed main shaft bearings 132 and 144 as shown in FIG. 2. Therefore, when the assembly is at rest, there is no possibility of oil leakage from the assembly. On the other hand, when the assembly is in operation, the oil O is thrown radially outward away from the bearings 132 and 144 by centrifugal force. The oil is circulated and splashed around the interior of hub 66 by the relative rotary motions of the planet gears 114 and hub 66. Thus, heat generated by the motor 62 and the gear reducer 64 is transferred to the oil which is circulated through the gap between disk 124 and hub end wall 66b and between end cover 138 and the stator case end wall 74b and between the stator case side wall 74a and the hub side wall 66a so that the heat is carried efficiently to the outside shell of the assembly which is both rotating and translating through the air stream where the heat is dissipated to the atmosphere. This enables the assembly to operate at maximum power for a prolonged period without overheating.

It is important to note also that the oil O is excluded from the stator case 74 and is completely isolated from the electrical wires 78a to 78c which conduct power from the connector 84 to the stator winding 78 so that the oil has no effect at all on the operation of the motor 62. Yet, there is only one bearing and one seal between the elements of motor 62 and the oil, i.e., bearing 104 and O-ring 109.

A modular motorized hub assembly constructed in accordance with FIGS. 2 to 5, having a length (not including the protruding shafts 68 and 72) of only about 4.25 inches, a diameter of less than 4.5 inches and a weight of less than 2.5 Kg. or 5.5 pounds is able

to produce a power output of up to 300 watts which is more than three times what a typical human can produce. Therefore, the hub assembly 26 is capable of propelling the FIG. 1 bicycle up relative steep grades with ease.

Refer now to FIGS. 1 and 6 which illustrate the rear wheel hub assembly 44 of the FIG. 1 bicycle. Assembly 44 is very similar to assembly 26 and accordingly, the similar parts thereof carry the same identifying numerals. The only real differences between the two are that the shaft 72 of assembly 44 is longer than the corresponding shaft of assembly 26 and the hub end wall is provided with an axially extending flange 172 which functions as a hub for the sprocket 46 and a one-way or overrunning clutch 174. Preferably, the inner surface of flange 172 is cone-shaped so that when hub 62 is rotated, the rotating flange cone expels dirt and moisture away from bearing 132. The inclusion of sprocket 46 enables the hub 66 of assembly 44 (and rear wheel 42 as a whole) to be rotated manually by sprocket 46 and its chain drive or by the motor 62 in assembly 44 or by a combination of both power sources. If the motor 62 rotates hub 66 faster than sprocket 46, the sprocket will free wheel due to the presence of the clutch 174.

If no power is applied by the bicycle's battery pack/controller unit 52 to the motor 62 in the rear hub assembly 44 and the rear hub 66 is rotated by way of the chain drive and sprocket 46, that motor can function as a generator to deliver electric current back to unit 52 in order to recharge the battery pack therein. In fact, to facilitate such recharging, the FIG. 1 bicycle may be equipped with a stand (not shown) which may be swung down to support the rear wheel 42 off the ground. The rider can then pedal the pedal crank 34

at a high rate. This will turn hub 66 to cause motor 62 to become an electric generator and to produce a DC output that will efficiently charge the battery pack in unit 52.

When the regeneration brake control 54 (FIG. 1) is actuated, the motor 62 in hub assembly 44 (and/or 26) will operate as a generator and brake to slow or stop the forward  
5 motion of the bicycle, recapturing and returning this energy to the battery pack in unit 52.

FIG. 7 shows a cantilevered modular motorized hub assembly 182 suitable for powering wheel chairs, all terrain vehicles, steerable front wheels of tricycles, etc. Assembly 182 is somewhat similar to assembly 26 depicted in FIG. 2. Therefore, corresponding parts bear the same identifying numerals. The main difference between the two  
10 modular assemblies is that assembly 182 is supported only by shaft 68, i.e., there is no shaft 72 at the opposite end of the assembly. Accordingly, shaft 68 is larger and shaped to be mounted to a suitable frame member or support S shown in phantom. The outer end segment of shaft 68 is exteriorly threaded to accommodate a nut 184 which may be screwed onto the end of the shaft to secure the assembly to support S. Also, the retaining  
15 disk 124 which retains the planetary gears 114 of gear reducer 64 has an axially extending stub shaft 186 in lieu of a shaft 72 which allows the end wall 66b of hub 66 to be continuous or closed over the end of stub shaft 76 as depicted in FIG. 7. An oil fill/drain fitting 187 is present in the hub end wall 66b allowing oil O to be introduced into the hub 66 for the reasons described above.

Finally, while assembly 182 could rotate a spoked wheel as in FIG. 2, the illustrated cylindrical wall 66a of hub 66 is instead surrounded by a small cast tire 188 of urethane or other such rugged, resilient material.

Turn now to FIG. 8 which shows a modular motorized hub assembly 192 for driving the wheel of a scooter, golf cart or other small vehicle. The interior of assembly 192 is essentially the same as assembly 26 depicted in FIG. 2. However, assembly 192 has a rotary hub 194 whose cylindrical side wall 194a is formed with a circumferential, radially extending flange 196 which leads to a tire rim 198. In use, the rim 198 may support a standard tire T. Preferably, a circular array of radial fins 199 provided in flange 196 to encourage centrifugal air circulation past, and cooling of, the hub 194.

Referring now to FIG. 9, there is shown there another modular hub assembly 202 which is cantilever-mounted like the one depicted in FIG. 7 and which is suitable for rotating a wheel with a standard tire as is the case with the FIG. 8 embodiment. The interior of assembly 202 is essentially the same as assembly 182 shown in FIG. 7. However, assembly 202 has an hub 204 which is different from those in the previously described embodiments. More particularly, the hub 204 is a cast part with a radially ribbed cylindrical side wall 204a for strength and cooling effect and an end wall 204b located at the end of the hub adjacent to shaft 68 instead of at the opposite end as in FIG. 7. The side wall 204a encircles the assembly's motor 62 but stops short of the gear reducer 64. Side wall 204a is formed with an external circumferential flange 206 midway along its length. Flange 206 provides a seat for an annular tire rim 208 having a radially inwardly extend-

ing fin or flange 208<sub>a</sub> whose inner diameter is slightly larger than that of the hub wall 204<sub>a</sub>. The tire rim may be releasably secured via rim 208<sub>a</sub> to hub flange 206 by a circular array of bolts 210 which extend through holes 212 in fin 208<sub>a</sub> and are turned down into threaded holes 214 in the hub flange 206.

5        Thus, if the tire and/or rim 208 should become damaged, it can be removed from the hub assembly 202 without having to detach that assembly from its support S. Hub assembly 202 also includes provision for mechanically braking hub 204. More particularly, an annular perforate brake disk 216 is mounted to the hub end wall 204<sub>b</sub> by means of a circular array of bolts 218 which extend through appropriate holes in the disk and are  
10       turned down into threaded holes 220 in end wall 204<sub>b</sub>. To slow the hub, the disk 216 may be frictionally engaged by conventional brake calipers C shown in phantom.

      The open end of hub 202 adjacent gear reducer 64 is closed by an end cover 218 which completely covers the stub shaft 186 projecting from the retaining disk 124. End cover 118 includes a cylindrical side wall 218<sub>a</sub> which is arranged to interlockingly seat  
15       against the rim of the hub side wall 204<sub>a</sub>. In this embodiment, the interior surface of the end cover side wall 218<sub>a</sub> is formed with a ring gear 222 which meshes with the teeth of the planet gears 114 of the gear reducer 64.

      The end cover 218 is secured to the hub wall 202<sub>a</sub> by a circular array of bolts 224 extending through holes 226 in the end cover and turned down into threaded passages 228  
20       in the hub side wall 204<sub>a</sub>.

Preferably, an oil fitting 232 and plug 234 are installed in the end cover 218 so that the hub 204 may be partially filled with cooling oil O as described above in connection with FIG. 2.

For relatively high power versions of the FIG. 9 assembly, e.g., 5 kilowatts or more, suitable for driving dune buggies, small city cars, etc., circulation of coolant oil O through the assembly may be facilitated by an external pump which circulates the oil in a closed loop between an external reservoir, the vehicle's radiator and the various hub assemblies on the vehicle. In this event, the necessary oil connections to each assembly may be made via fittings on shaft 68 in lieu of the fittings 232, 234 on hub 204. These shaft fittings would route the oil to and from the interior of the assembly. A solenoid valve may be incorporated in the external oil loop to turn on the external pump at vehicle start-up so as to "prime" the assembly's internal oil pump comprised of the rotating sun gear 122 and planet gears 114 as described above.

A distinct advantage of the FIG. 9 hub assembly 202 is the fact that the end cover 218 may be removed to gain access to the interior of the assembly for maintenance and repair purposes without having to remove the hub from its support S or the wheel rim 208 from the hub. Also, if the rotor 88, pinion 122 and/or ring gear 222 becomes damaged, only the end cover 218 has to be replaced.

Another advantage of the FIG. 9 construction is that the single stage gear reducer 64 can easily be substituted for by a two-stage gear reducer 236 as shown in FIG. 9A so as to give the overall hub assembly a higher gear reduction ratio, e.g., 15:1.



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The two-stage gear reducer 236 shown in FIG. 9A differs from the single stage gear reducer 64 described previously primarily due to the fact that it has two-part planet gears 238 rotatably mounted on the posts 112 which project from the retaining disk 106. Each of the two gears 238 includes a first relatively large diameter spur gear section 238a which meshes with sun gear 122 and a second smaller diameter spur gear section 238b  
5 which extends axially beyond the corresponding post 112. As before, the planet gears 238 are rotatably secured to posts 112 by a retaining disk 242. Here, however, the retaining disk has receptacles or sleeves 244 which project through gear section 238b and are counterbored to capture the ends of the associated posts 112. Sleeves 244 provide seats  
10 for circular bearings 246 so that the gear segments 238b are free to rotate relative to sleeves 244. The retaining disk 242 is secured to the posts by threaded fasteners 248 which extend through the sleeves and are screwed into the ends of posts 112 as before.

The assembly in FIG. 9A is provided with an end cover 252 which is similar to end cover 218 in FIG. 9, except it is dimensioned and shaped to accommodate the extra  
15 length of the two-stage gear reducer 236. Most importantly, the end cover 252 has a stepped side wall having a first side wall portion 252a which encircles the spur gear sections 238b. That portion is formed on its interior surface with a ring gear 254 which meshes with the teeth of the spur gear sections 238b of both planet gears 238. A second side wall portion 252b of end cover 252 encircles the spur gear sections 238a with appreciable clearance and seats against the end of the hub side wall 204a. As in the FIG. 9  
20 hub assembly, the end cover 252 is secured to the hub side wall 204a by a circular array of bolts 256.

Of course, the two-piece hub construction with the separable ring gear and one or two-stage gear reducer shown in FIGS. 9 and 9A can also be incorporated into the hub assemblies depicted in FIGS. 2 and 7 to obtain the above-described advantages for those assemblies, i.e., easy repair and change of gear reduction ratio. Similarly, other aspects  
5 of the various assembly embodiments described above are interchangeable depending upon the particular application.

It will be seen from the foregoing that my modular motorized wheel hub assembly obtains distinct advantages in terms of the ability to produce a high output torque in a small compact package without the assembly overheating even after a long period of  
10 continuous use. The modular assembly is adaptable to a wide variety of wheeled vehicles from small bicycles and tricycles to large on and off road cars and trucks. The assembly is operable as a motor or a generator so that it can function as a drive motor or brake. Despite all of these advantages, the assembly is relatively inexpensive to make and easy to assemble and repair. Therefore, it should not add appreciably to the overall cost of the  
15 vehicle in which it is installed.

In fact, my hub assemblies for larger vehicles (FIGS. 7-9) have far fewer parts than a competing internal compensation engine driver vehicle. As drive shafts, couplings, clutches, differentials, front or rear axles, starters, torque converters as well as anti-lock brake and pollution control systems are unnecessary. Overall, with my modular  
20 electric wheel system, the life of the entire vehicle can be reasonably extended, as the en-

tire motor, drive train and wheel system can be removed and replaced in minutes by un-  
doing not much more than a single bolt; see e.g., FIG. 9, bolt 184.

It will thus be seen that the objects set forth above, among those made apparent  
from the preceding description are efficiently attained and since certain changes may be  
5 made in the above construction without departing from the scope of the invention, it is  
intended that all matter contained in the above description or shown in the accompanying  
drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the  
generic and specific features of the invention described herein.

10 Having described the invention and what is claimed as new and secured by Letters  
Patent is:

[illegible][illegible]

21 a ring gear formed in the housing interior surface opposite the planet gears, said  
22 ring gear being in meshing engagement with the planet gears so that when an electric cur-  
23 rent is applied to the stator winding, the rotor rotates relative to the first and third shafts at  
24 a selected speed and the hub rotates relative to the first and third shafts at a lesser speed.

1 2. The assembly defined in claim 1 and further including means for sealing the inte-  
2 rior of the housing from the interior of the hub.

1 3. The assembly defined in claim 2 and further including means for introducing a  
2 thermally conductive liquid into the hub so that when the hub rotates relative to the first  
3 and third shafts, said liquid is circulated through said gap so that heat generated within  
4 the housing is conducted by the liquid to the hub walls and thence to the outside.

1 4. The assembly defined in claim 1 wherein said third shaft projects through the hub  
2 second end wall.

1 5. The assembly defined in claim 1 wherein the hub second end wall covers the third  
2 shaft so that the assembly can be cantilever-mounted via the first shaft.

1 6. The assembly defined in claim 1 wherein the rotor, housing side wall and hub side  
2 wall are cylindrical.

1 7. The assembly defined in claim 1 wherein the stator winding is a toroidal, 3 wire, 3  
2 phase WYE-connected winding.

1 8. The assembly defined in claim 7 wherein the rotor has a plurality of poles.

1 9. The assembly defined in claim 1 wherein  
2 the planet gears are rotatably mounted to axles projecting from the housing  
3 second end wall, and  
4 the means for connecting include a retainer plate releasably mounted to  
5 said axles, said third shaft extending axially from the retainer plate.

1 10. The assembly defined in claim 9 wherein the third shaft projects through the hub  
2 second end wall.

1 11. The assembly defined in claim 9 wherein the hub second end wall covers the third  
2 shaft so that the assembly can be cantilever-mounted via the first shaft.

1 12. The assembly defined in claim 1 and further including  
2 a sprocket, and  
3 a one-way clutch connected between the sprocket and the hub second end  
4 wall so that the sprocket can rotate about said axis in only one direction relative to the  
5 hub.

1 14. The assembly defined in claim 1 and further including  
2 a tire rim surrounding the hub side wall;  
3 a plurality of spokes having corresponding first and second ends;  
4 means for connecting the first ends of the spokes to the hub, and  
5 means for connecting the second ends of the spokes to the rim so that the  
6 rim is centered on said axis.

1 15. The assembly defined in claim 1 and further including  
2 a tire rim surrounding the hub side wall, and  
3 means for connecting the tire rim to the hub side wall.

1 16. The assembly defined in claim 15 wherein the means for connecting are releasable  
2 so that the rim can be separated from the hub.

1 17. The assembly defined in claim 15 and further including a brake disc releasably  
2 mounted to one of said hub end walls so as to be centered on said axis.

1 18. The assembly defined in claim 1 and further including a tire engaged around the  
2 hub side wall.

1 19. The assembly defined in claim 1 wherein said ring gear is formed in the hub side  
2 wall.

1 20. The assembly defined in claim 1 wherein  
2 the hub second end wall has a cylindrical skirt which forms an extension  
3 of the hub side wall, and  
4 said ring gear is formed in said skirt.

1 21. The assembly defined in claim 20 wherein  
2 the hub second end wall is a separate part from the hub side wall, and  
3 means for releasably securing the hub second end wall to the hub side  
4 wall.

1 22. The assembly defined in claim 21 wherein each planet gear has a relatively large  
2 diameter first section in meshing engagement with the pinion and a smaller diameter sec-  
3 ond section collinear to the first section and in meshing engagement with the ring gear so  
4 that the assembly has two-stage gear reduction.

1 23. The assembly defined in claim 1 wherein each planet gear has a relatively large  
2 diameter first section in meshing engagement with the pinion and a smaller diameter sec-  
3 ond section collinear to the first section and in meshing engagement with the ring gear so  
4 that the assembly has two-stage gear reduction.



1 24. The assembly defined in claim 1 wherein the hub is less than 5 inches in diameter  
2 and the assembly has a gear reduction ratio exceeding 10:1.

1 25. The assembly defined in claim 1 wherein the housing second end wall is separable  
2 from the housing side wall and the hub first end wall is separable from the hub side wall.

1 26. The assembly defined in claim 1 and further including  
2 an electrical connector mounted to the first shaft;  
3 electrical leads extending from the connector along the first shaft to the  
4 interior of the housing, and  
5 means for connecting the leads to the stator winding.

1 27. The assembly defined in claim 1 and further including  
2 first means acting between the rotor and the housing first end wall for bias-  
3 ing the rotor toward the third shaft, and  
4 second means acting between the means for connecting and the hub sec-  
5 ond end wall for biasing the housing toward the first shaft.

1 28. A motorized wheel hub assembly comprising

2 a sealed motor section having first and second end walls and a side wall  
3 extending between the end walls, a first shaft extending from the first end wall and a ro-  
4 tary second shaft extending from the second end wall coaxial to the first shaft, and  
5 a gear reduction section adjacent to the second end wall, said gear reduc-  
6 tion section including a pinion at the end of the rotary shaft, a plurality of planet gears  
7 rotatably mounted to the second end wall in meshing engagement with the pinion, a third  
8 shaft connected to the second end wall, said third shaft being separate from but coaxial to  
9 the first and second shafts, a hub having an interior surface closely surrounding the motor  
10 section and planet gears and being rotatably coupled to the first and third shafts, and a  
11 ring gear formed at the interior surface of the hub in meshing engagement with the planet  
12 gears so that when the second shaft rotates at a selected speed, the hub rotates relative to  
13 the first and third shafts at a lesser speed.

1 29. The assembly defined in claim 28 and further including means for introducing a  
2 thermally conductive liquid into the hub so that when the hub rotates, the liquid is circu-  
3 lated within the hub so that heat generated within the motor section is conducted by the  
4 liquid to the hub and thence to the outside.

1 30. The assembly defined in claim 28 wherein the first and third shafts project from  
2 the hub.

1     32.     The assembly defined in claim 28 wherein  
2                    the hub has first and second end walls and a side wall extending between  
3     said end walls, and

1     33.     The assembly defined in claim 32 wherein said ring gear is formed in the hub side  
2     wall.

1     34.     The assembly defined in claim 32 wherein  
2                     the hub second end wall has a cylindrical skirt which forms an extension  
3     of the hub side wall, and  
4                     said ring gear is formed in said skirt.

1     35.     The assembly defined in claim 32 wherein  
2                    the hub second end wall is a separate part from the hub side wall, and  
3                    means for releasably securing the hub second end wall to the hub side  
4     wall.

1     36.     The assembly defined in claim 35 wherein each planet gear has a relatively large  
2     diameter first section in meshing engagement with the pinion and a smaller diameter sec-

3    ond section collinear to the first section and in meshing engagement with the ring gear so  
4    that the assembly has two-stage gear reduction.

1    37.    The assembly defined in claim 28 wherein each planet gear has a relatively large  
2    diameter first section in meshing engagement with the pinion and a smaller diameter sec-  
3    ond section collinear to the first section and in meshing engagement with the ring gear so  
4    that the assembly has two-stage gear reduction.

## ABSTRACT OF THE DISCLOSURE

A motorized wheel hub assembly includes a sealed motor section having first and second coaxial shafts extending from the motor section, the second shaft being a rotary shaft and a gear reduction section adjacent to the motor section, the gear reduction section including a pinion at the end of the rotary shaft, a plurality of planet gears rotatably mounted to the housing in meshing engagement with the pinion and a third shaft connected to the motor housing, all of the shafts being separate but coaxial. A hub having an interior surface closely surrounds the motor and gear reduction sections and is rotatably coupled to the first and third shafts. A ring gear formed in the interior surface of the hub is in meshing engagement with the planet gears so that when the second shaft rotates at a selected speed, the hub rotates relative to the first and third shafts at a lesser speed. Preferably, the hub is partially filled with oil to conduct heat from the motor section to the outside.

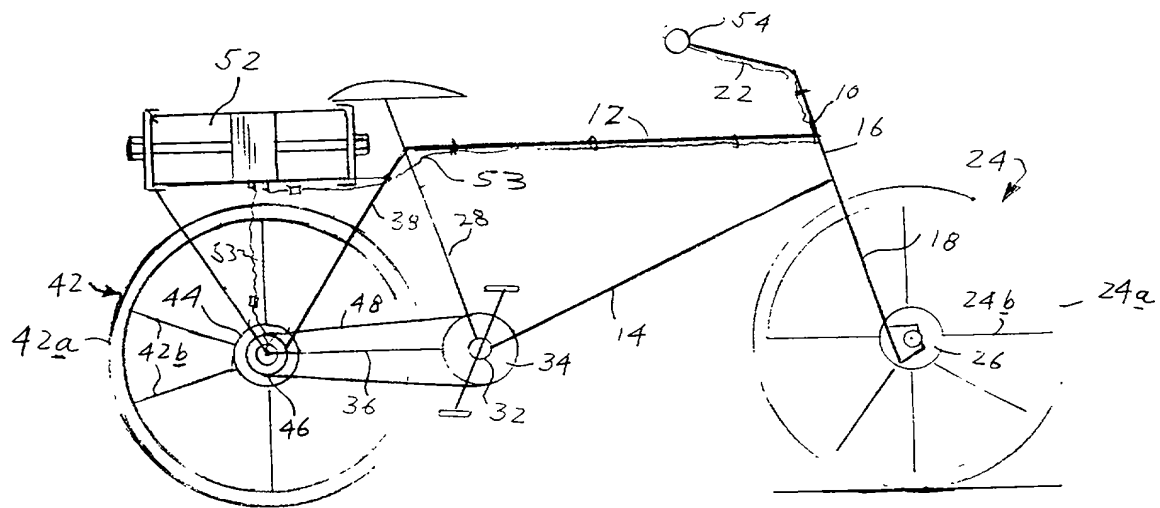


FIG. 1

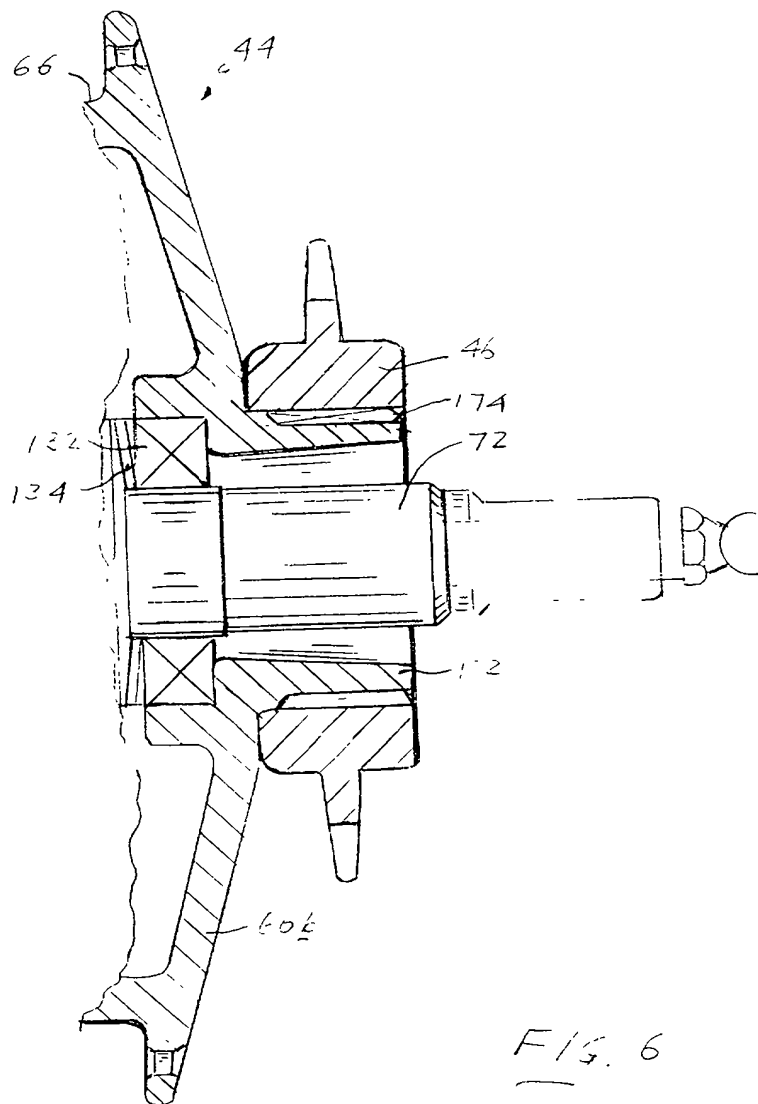
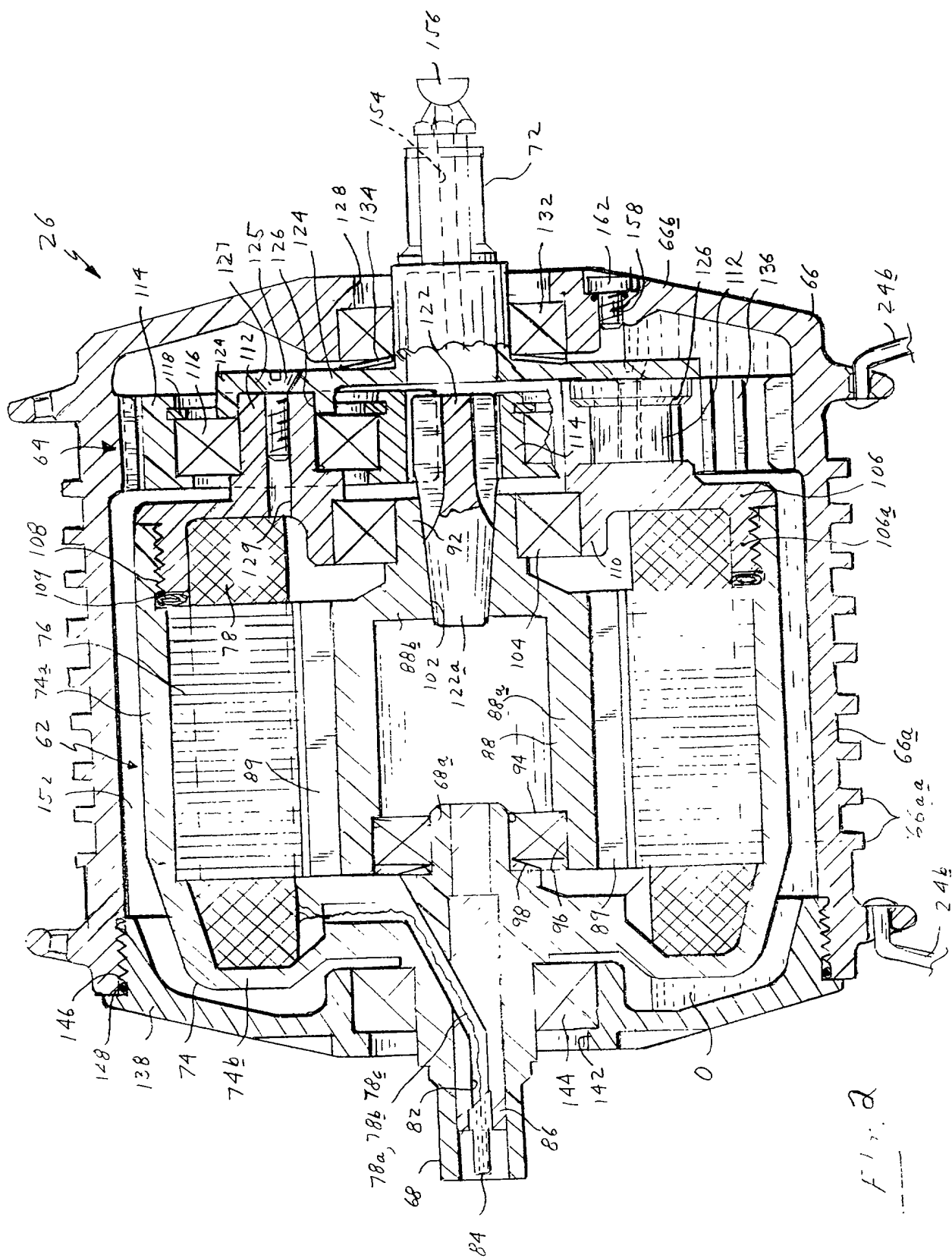


FIG. 6



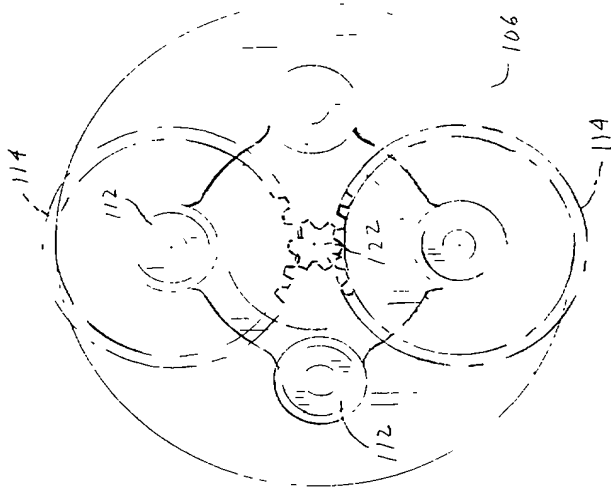


FIG. 4

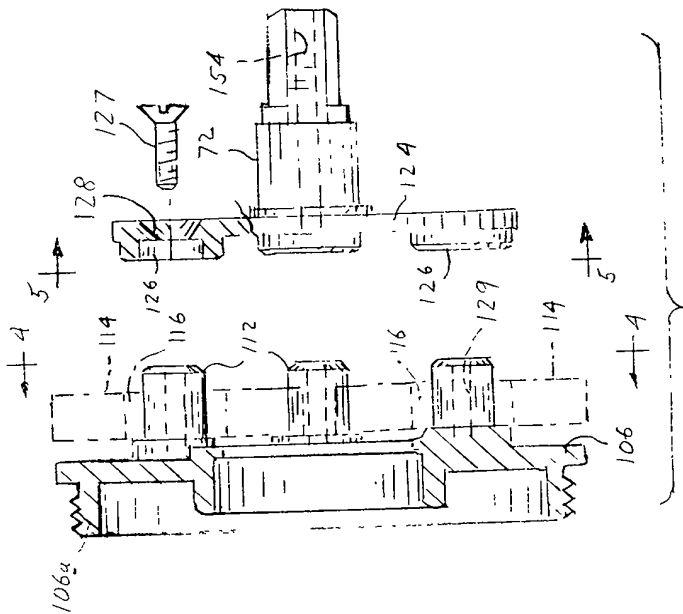


FIG. 5

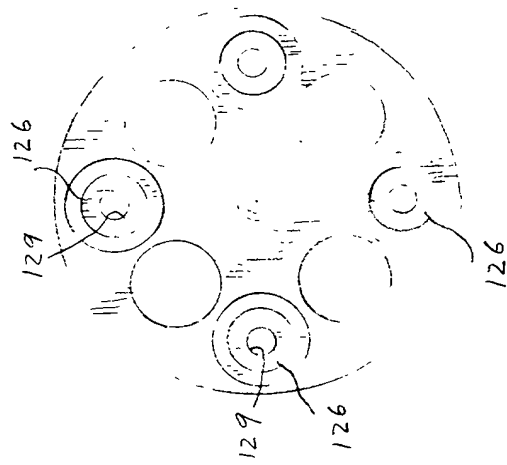
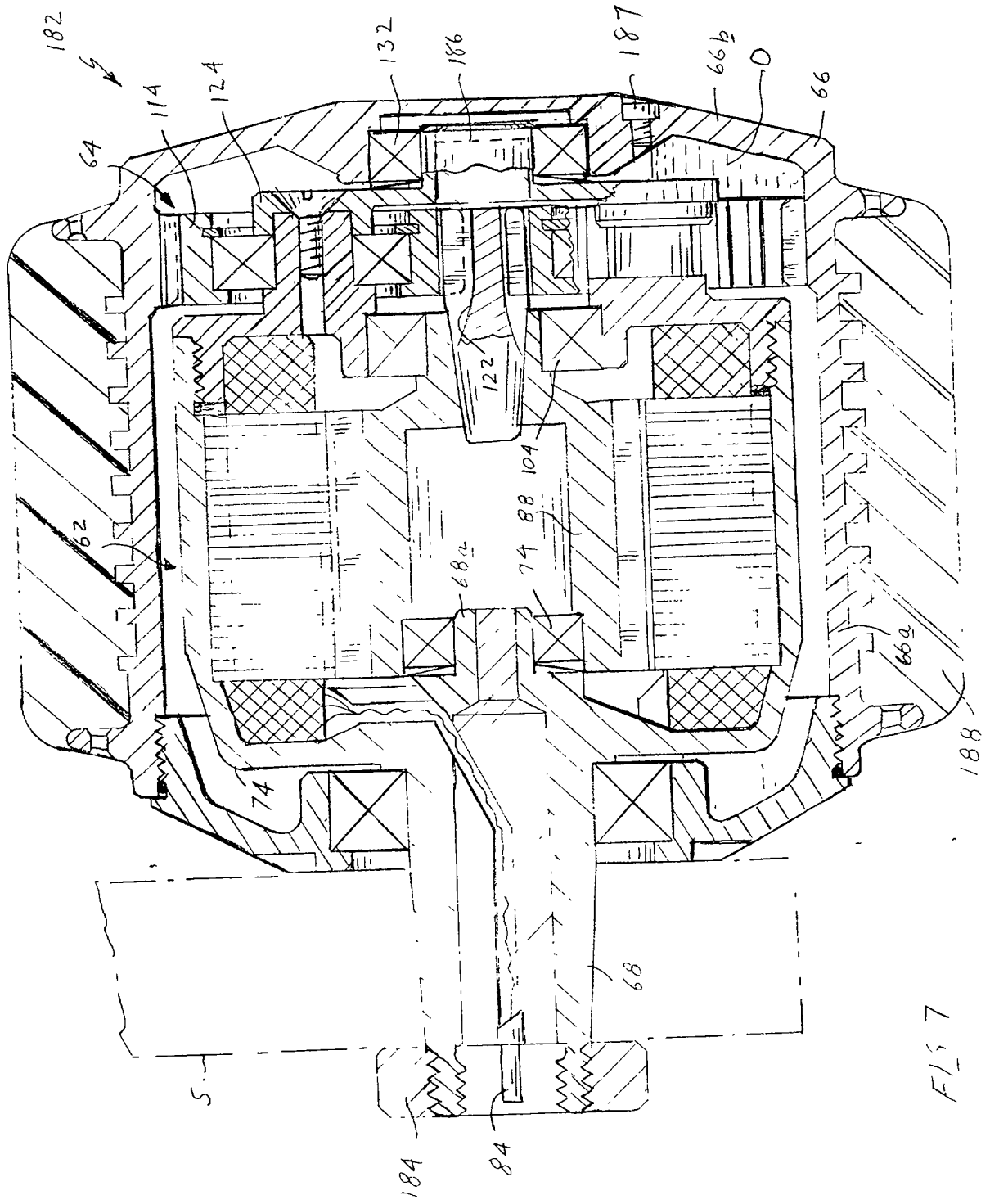


FIG. 6





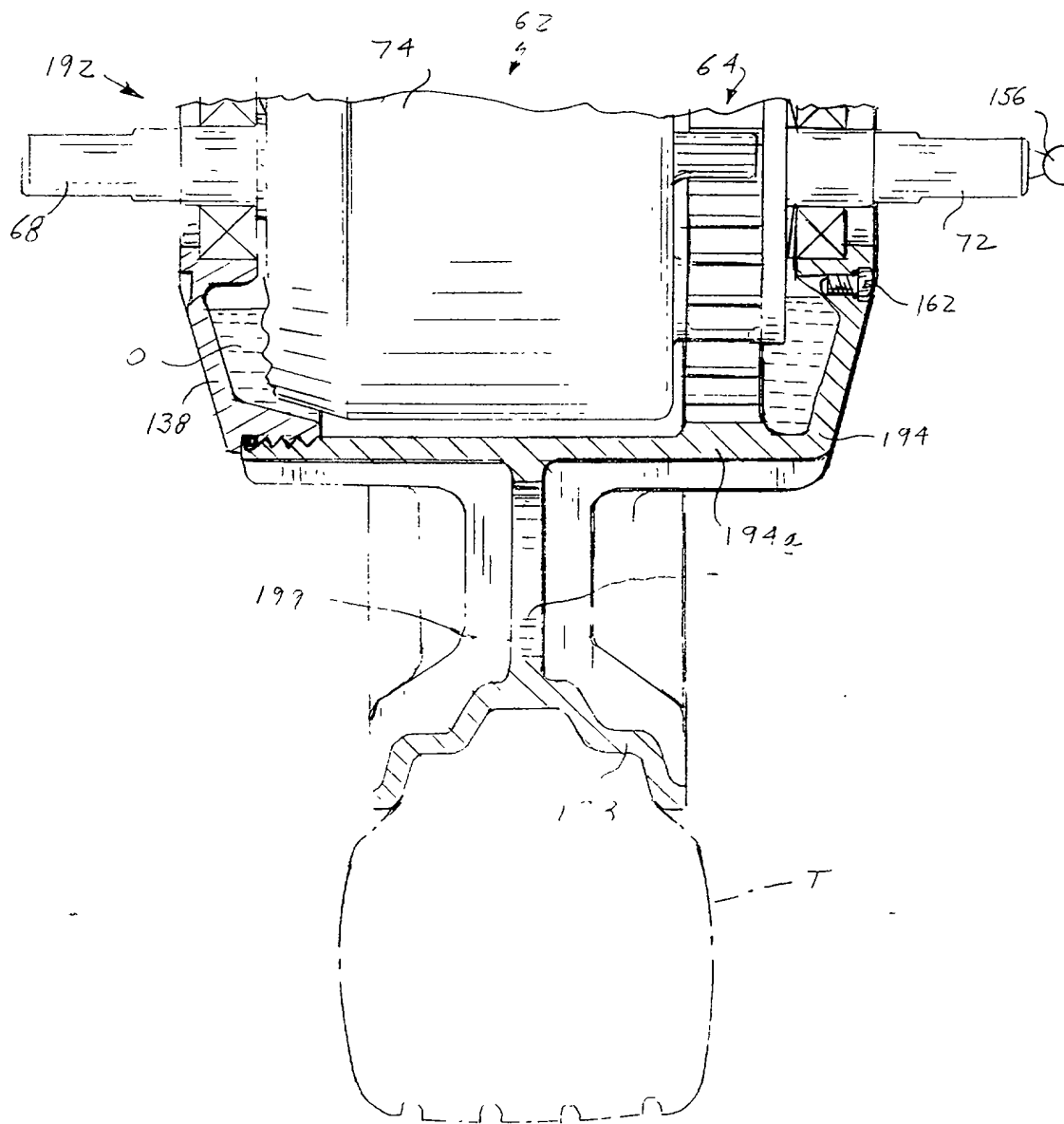


FIG 8

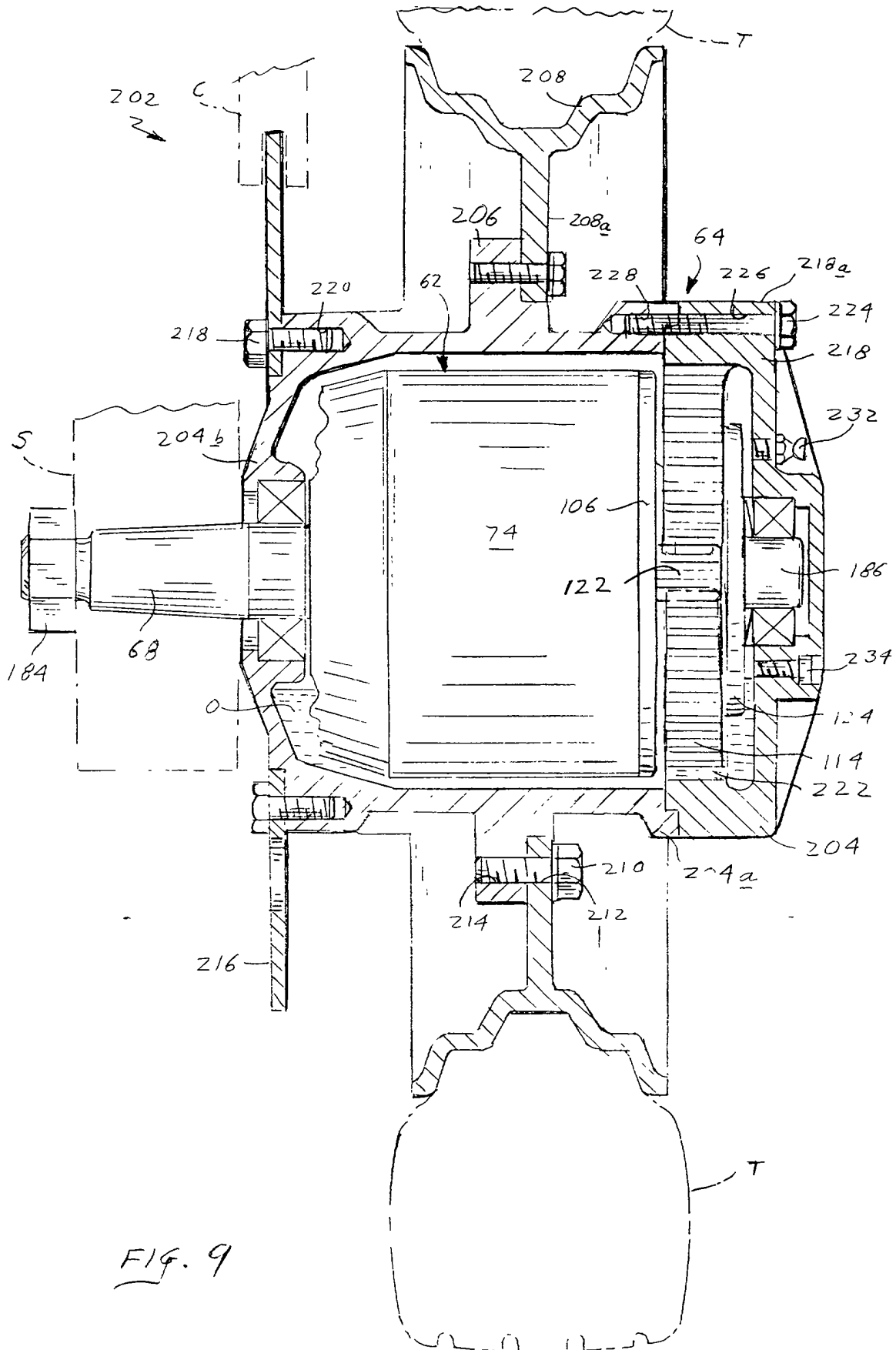


FIG. 9

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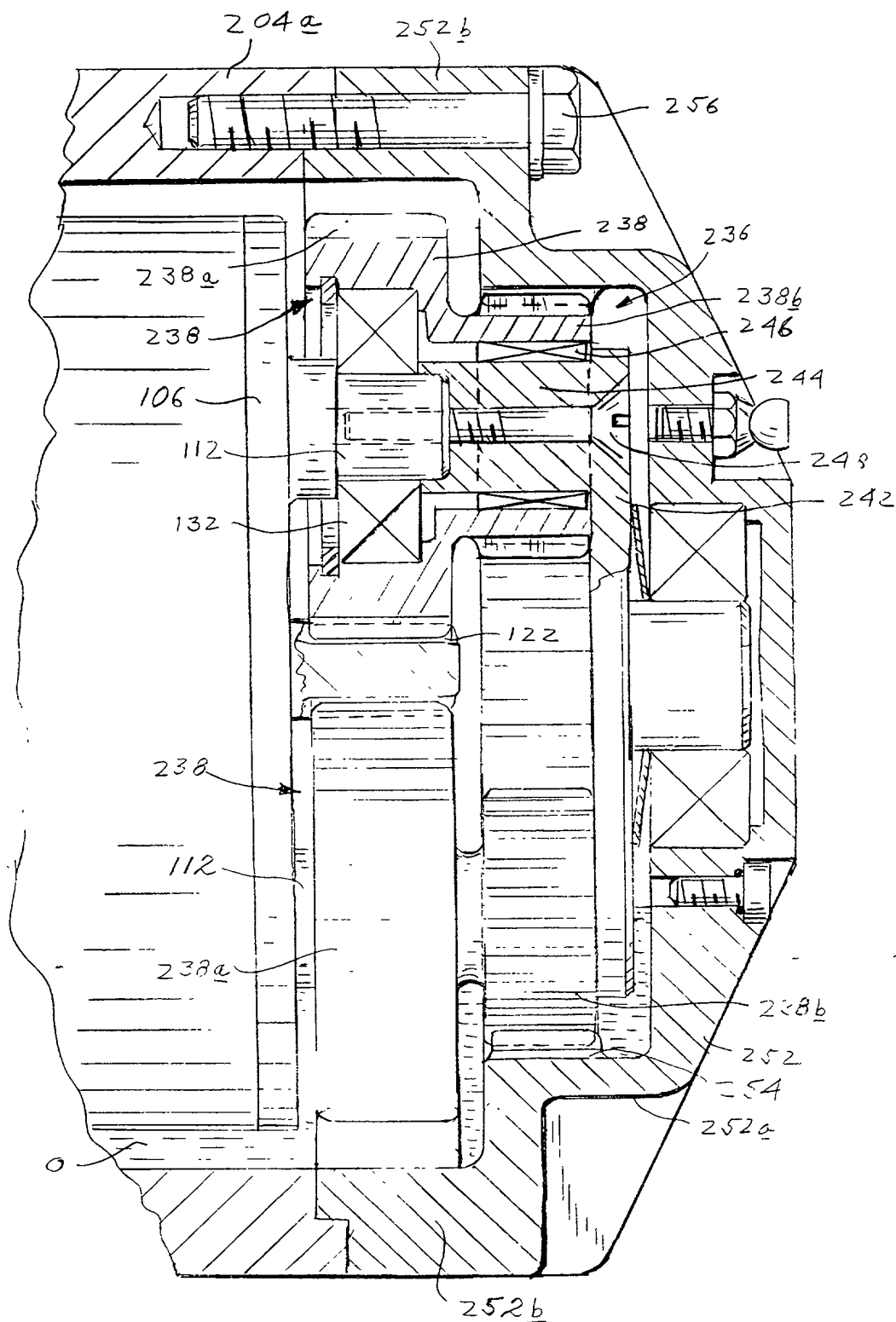


FIG 9A

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In Re The Application of: )  
Orville J. Birkestrand )  
Serial No.: Not Yet Assigned ) Examiner: Not Yet Assigned  
Filed: Herewith ) Art Unit: Not Yet Assigned  
For: MODULAR MOTORIZED ELEC- )  
TRIC WHEEL HUB ASSEMBLY )  
FOR BICYCLES AND THE LIKE )

**DECLARATION BY INDEPENDENT INVENTOR CLAIMING  
SMALL ENTITY STATUS UNDER 37 CFR §§1.9(f) and 1.27(b)**

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR §1.9(c) for purposes of paying reduced fees under §41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled MODULAR MOTORIZED ELECTRIC WHEEL HUB ASSEMBLY FOR BICYCLES AND THE LIKE described in the specification identified above.

I have not assigned, granted, conveyed, or licensed and am under no obligation under contract or law to assign, grant, convey, or license any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR §1.9(c) if that person had made the invention, or to any concern that would not qualify as a small business concern under 37 CFR §1.9(d) or any organization which would not qualify as a nonprofit organization under 37 CFR §1.9(e).

Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

None

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small-entity status prior to paying, or at

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

DATE:

Orville J. Birkestrand

## DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below-named inventor, I hereby declare that:

My residence, post-office address, and citizenship are as stated below next to my name.

I believe I am the original, first, and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled MODULAR MOTORIZED ELECTRIC WHEEL HUB ASSEMBLY FOR BICYCLES AND THE LIKE, the specification of which is attached hereto and identified by Cesari and McKenna File No. 102047-0003.

I hereby state that I have reviewed and understand the contents of the above-identified application specification, including the claims, as amended by any amendment specifically referred to herein.

I acknowledge the duty to disclose all information known to me that is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me on the same subject matter having a filing date before that of the application on which priority is claimed: None.

I hereby claim the benefit under Title 35, United States Code §119(e) of the following U.S. provisional application: None.

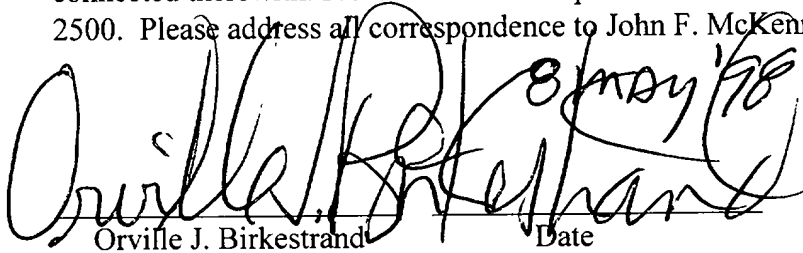
I hereby claim the benefit under Title 35, United States Code §120, of the United States Application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United State Code, §112, I acknowledge the duty to disclose all information that is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56, and which became available to me between the filing date of the prior application and the national or PCT international filing date of this application: None.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of

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Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint Michael E. Attaya, Reg. No. 31,731; Charles J. Barbas, Reg. No. 32,959; Joseph H. Born, Reg. No. 28,283; Robert A. Cesari, Reg. No. 18,381; Steven J. Frank, Reg. No. 33,497; Christopher K. Gagne, Reg. No. 36,142; William A. Loginov, Reg. No. 34,863; Robert A. Mazzaresse, Reg. No. P42,852; John F. McKenna, Reg. No. 20,912; Martin J. O'Donnell, Reg. No. 24,204; Thomas C. O'Konski, Reg. No. 26,320; Michael R. Reinemann, Reg. No. 38,280; Rita M. Rooney, Reg. No. 30,585; Heather B. Shapiro, Reg. No. 41,305; and Patricia A. Sheehan, Reg. No. 32,301, Cesari and McKenna, LLP, 30 Rowes Wharf, Boston, Mass. 02110, jointly, and each of them severally, my attorneys and attorney, with full power of substitution, delegation and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent and Trademark Office connected therewith. Please direct all telephone calls to John F. McKenna at (617) 951-2500. Please address all correspondence to John F. McKenna.

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